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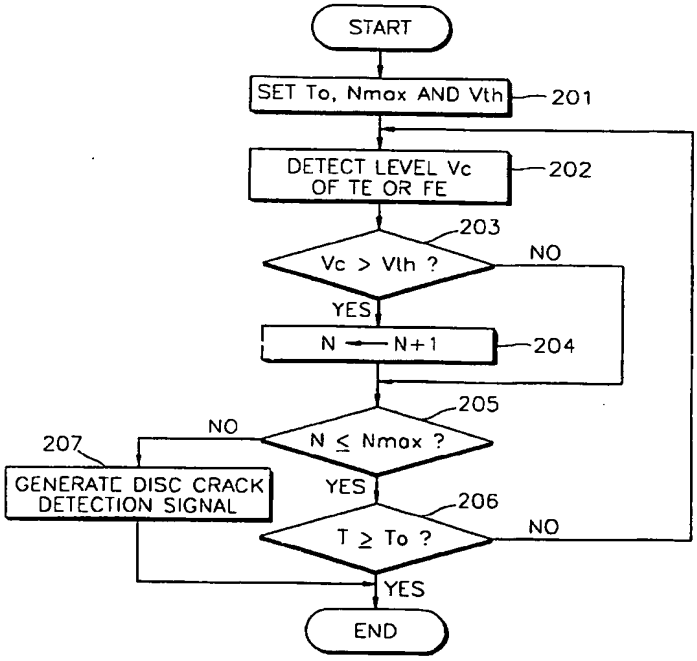
(54) Disc crack detection method and method of controlling speed of disc drive using the same

(57) A method of detecting a crack in a disc loaded on a disc drive and a method of automatically lowering a target speed in response to the detection of a crack in order to stabilize the disc drive are provided. According to the methods, it is automatically determined whether a disc loaded on a disc drive has a crack in a specific mode, and a target speed is automatically changed into a low speed when it is determined that the disc has a crack. Therefore, the crack state of the disc is exactly checked during action of the disc drive, the percentage of error occurrence is decreased, and the probability of damage to the disc is reduced.

FIG. 2



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Description

[0001] The present invention relates to a method of controlling a disc drive, and more particularly, to a method of detecting a crack on a disc loaded on a disc drive and a method of automatically lowering a target speed in response to the detection of a crack in order to stabilize the disc drive.

[0002] Optical disc recording media include compact discs such as CD-ROMs and digital versatile discs or DVDs suitable for multimedia. Disc drives corresponding to these optical disc recording media read data by radiating a laser beam at a track on a turning disc using an optical pickup and detecting light reflected from the track, or record data by radiating a laser beam which is recording data after having been modulated.

[0003] To increase the data processing speed of such a disc drive, the system has been improved to increase the speed of rotation of a disc. The speed factor of present disc drives has rapidly increased to 48 or more. As the speed of a disc drive is increased, probability that an error occurs during data recording or reproduction increases when a disc has a defect. In particular, when a disc having a crack is rotated at a high speed, the disc can be eventually broken. This may fatally damage the disc drive and, moreover, threatens the safety of users.

[0004] A conventional disc drive cannot detect a crack on a disc and rotates a disc at a maximum speed set regardless of existence/nonexistence of a crack. Accordingly, the disc drive can be fatally damaged. Moreover, the safety of users may be threatened.

[0005] To solve the above problems, it is a first aim of embodiments of the present invention to provide a disc crack detection method of detecting a crack in a disc with a minimum program load in a disc drive.

[0006] It is a second aim of embodiments of the present invention to provide a method of controlling the speed of the disc drive using the disc crack detection method by automatically lowering the target speed of the disc drive when a crack is detected in the disc.

[0007] According to a first aspect of the present invention, there is provided a method of detecting a crack in a disc loaded on a disc drive, the method comprising the steps of: (a) determining whether the disc drive satisfies an initially set condition for execution of a disc crack detection algorithm; (b) counting the number of a type of error signals whose levels exceed a predetermined threshold voltage, at predetermined measuring time periods, when it is determined that the disc drive satisfies the initially set condition in the step (a); and (c) generating a disc crack detection signal when the number of the type of error signals counted in the step (b) exceeds a predetermined number.

[0008] Preferably, the condition for execution of a disc crack detection algorithm is set such that the disc crack detection algorithm is performed whenever a play mode is changed into a pause mode.

[0009] The condition for execution of a disc crack detection algorithm may be set such that the disc crack detection algorithm is performed at predetermined time intervals in a pause mode.

[0010] The condition for execution of a disc crack detection algorithm is preferably set such that the disc crack detection algorithm is performed whenever the target speed of the disc drive is changed.

[0011] The condition for execution of a disc crack detection algorithm may be set such that the disc crack detection algorithm is performed whenever the target speed increases.

[0012] The method may further comprise the step of transmitting a warning message data to a host computer when the disc crack detection signal is generated.

[0013] According to another aspect of the invention, there is provided a method of controlling the speed of a disc drive, comprising the steps of: (a) determining whether a command instructing changing of the speed of the disc drive to a target speed is input; (b) controlling the speed of a spindle motor to be the target speed according to the command; (c) counting the number of a type of error signals whose levels exceed a predetermined threshold voltage, at predetermined measuring time periods until the current speed reaches the target speed; (d) generating a disc crack detection signal when the number of the type of error signals counted in the step (c) exceeds a predetermined number; and (e) changing the target speed into a predetermined low speed when the disc crack detection signal is generated.

[0014] In a third aspect there is provided a method of controlling the speed of a disc drive, comprising the steps of: (a) determining whether a current play mode is changed into a pause mode; (b) counting the number of a type of error signals whose levels exceed a predetermined threshold voltage, at predetermined measuring time periods, when it is determined that the play mode is changed into the pause mode in the step (a); (c) generating a disc crack detection signal when the number of the type of error signals counted in the step (b) exceeds a predetermined number; and (d) changing a target speed into a predetermined low speed when the disc crack detection signal is generated.

[0015] In each of the above aspects, the type of error signals may comprise tracking error signals or focus error signals.

[0016] For a better understanding of the invention, and to show how embodiments of the same may be carried into effect, reference will now be made, by way of example, to the accompanying diagrammatic drawings in which:

Figure 1 is a diagram of the configuration of a disc drive to which the present invention is applied;

Figure 2 is a flowchart of a disc crack detection method according to an embodiment of the present invention;

Figure 3 is a flowchart of a method of controlling the speed of a disc drive according to a first embodiment of the present invention;

Figure 4 is a flowchart of a method of controlling the speed of a disc drive according to a second embodiment of the present invention;

Figure 5 is a flowchart of a method of controlling the speed of a disc drive according to a third embodiment of the present invention;

Figure 6 is a flowchart of a method of controlling the speed of a disc drive according to a fourth embodiment of the present invention;

Figures 7A and 7B are waveform diagrams of a tracking error signal and a focus error signal, respectively, with respect to a normal disc in a pause mode; and

Figures 8A and 8B are waveform diagrams of a tracking error signal and a focus error signal, respectively, with respect to a disc with a crack in a pause mode.

[0017] Referring to Figure 1, a disc drive includes a disc 101, a turn table 102, a spindle motor 103, a spindle motor driver 104, a pickup 105, radio frequency (RF) amplifier 106, a signal processor 107, a laser driver 108, a system controller 109, a memory 110, an interface unit 111 and a host computer 112. The general operations of these members constructing a disc drive will be briefly described below.

[0018] The disc 101 is loaded on the turn table 102 and turned by the spindle motor 103 at a constant linear velocity during reproduction. The pickup 105 reads data which has been recorded to the disc 101 in the form of embossed pits or phase change pits.

[0019] A spindle frequency generator (FG) is installed at the spindle motor 103 to perform servo control on the spindle motor 103 so that a FG pulse is generated in synchronization with the rotation of the spindle motor 103. The system controller 109 detects information on the rotation of the spindle motor based on the spindle FG pulse and controls the spindle motor 103 to rotate at a target speed.

[0020] The pickup 105 includes a laser diode functioning as a laser light source, a photodetector for detecting reflected light and a variety of optical lenses. The pickup 105 emits optical signals output from the laser diode to the disc 101, detects light reflected from the disc 101 at the photodetector, converts the detected light into an electrical signal and outputs the electrical signal to the RF amplifier 106.

[0021] The RF amplifier 106 includes a current-to-voltage converter circuit, a matrix operation/amplification circuit and so on in order to process currents output from a plurality of light receiving devices serving as the photodetector of the pickup 105. The RF amplifier 106 generates signals necessary for processing a matrix operation. For example, a RF sum signal SUM which is reproduced data, a focus error signal FE and a tracking error signal TE are generated.

[0022] The signal processor 107 includes hardware and software for performing EFM demodulation, MPEG decoding and error correction.

[0023] The laser driver 108 generates a driving current so that the laser diode of the pickup 105 can generate recording and reproducing laser power.

[0024] The memory 110 stores a variety of execution programs and data for driving the disc drive and programs and data related to a disc crack detection method and to a method of controlling the speed of the disc drive using the disc crack detection method.

[0025] The interface unit 111 is connected to the host computer 112 outside and communicates reproduced data and a variety of commands with the host computer 112.

[0026] A disc crack detection method will be described in detail with reference to Figures 1 and 2. A crack detection algorithm according to the present invention is based on the fact that a tracking error signal and a focus error signal which are different from those generated with respect to a normal disc are generated with respect to a disc having a crack. In other words, as shown in Figures 7A and 7B, abnormal pulses rarely occur in a tracking error signal and a focus error signal when a disc is normal. On the contrary, as shown in Figures 8A and 8B, the tracking error signal and the focus error signal include abnormal pulses when a disc has a crack.

[0027] Accordingly, a crack detection algorithm according to the present invention counts the number of abnormal pulses contained in the tracking error signal or the focus error signal for a predetermined measuring time to determine whether a disc has a crack.

[0028] The following description concerns a crack detection algorithm according to the present invention. In step 201, a measuring period To, a threshold voltage Vth and a maximum number Nmax which are necessary for determining whether a disc has a crack are set based on experimental statistics, and the set values are stored in the memory 110 as initial values. The number of abnormal pulses is counted for the measuring period To. The threshold voltage Vth is used for detecting an abnormal pulse occurring in a tracking error signal TE or a focus error signal FE due to a crack on a disc. The maximum number Nmax indicates the number of abnormal pulses contained in the tracking error signal TE or the focusing error signal FE for the measuring period To, and is referred to determine whether a disc has a crack.

[0029] In step 202, the system controller 109 detects and monitors the level Vc of the tracking error signal TE or the focus error signal FE when a disc drive satisfies

a condition for execution of the disc crack detection algorithm. That is, the disc crack detection algorithm may be executed when a play mode is changed into a pause mode, may be repeated at predetermined time intervals in the pause mode, or may be executed whenever a target speed is changed.

[0030] In step 203, the level Vc of the tracking error signal or the focus error signal FE detected in step 202 is compared with the threshold voltage Vth set and stored in the memory 110 in step 201. In step 204, counting is performed by increasing the number N of pulses by one when the detected level Vc of the tracking error signal TE or the focus error signal FE exceeds the threshold voltage Vth.

[0031] In step 205, it is determined whether the counted number N exceeds the maximum number Nmax set and stored in the memory 110 in the step 201. In step 207, a disc crack detection signal indicating that the disc has a crack is generated when the counted number N exceeds the maximum number Nmax.

[0032] However, when it is determined that the counted number N does not exceed the maximum number Nmax in the step 205, it is determined whether a measuring time T is no less than the measuring period To in step 206. When it is determined that the measuring time T is no less than the measuring period To, it is concluded that a crack is not detected during the measuring period To so that the process ends. On the other hand, when it is determined that the measuring time T is less than the measuring period To in the step 206, the process goes back to the step 202, and the steps described above are repeated until the measuring period To elapses.

[0033] In the above disc crack detection algorithm, one of a tracking error signal and a focus error signal is selected, and the level of the selected signal is compared with a threshold voltage for a predetermined period of time to determine whether a disc has a crack. Alternatively, both the tracking error signal and the focus error signal can be used to determine whether a disc has a crack.

[0034] The following description concerns a method of controlling the speed of a disc drive using the disc crack detection algorithm described above. A method of controlling the speed of a disc drive according to a first embodiment of the present invention will be described first with reference to Figures 1 and 3.

[0035] Once a command for changing the speed of a disc drive is transmitted from the host computer 112 to the system controller 109 through the interface unit 111, in step 301 the system controller 109 analyzes the speed changing command and sets a target speed St and circuit control factors related to the target speed St. Next, a spindle motor is controlled as follows.

[0036] In step 302 the target speed St set in the step 301 is compared with a current speed Sc. If the target speed St is lower than the current speed Sc, in steps 308 and 309 spindle break is performed until the speed of the disc drive becomes the target speed St to decrease the speed of the spindle motor 103. If the target speed St is higher than the current speed Sc, in step 303 spindle kick is performed to increase the speed of the spindle motor 103.

[0037] While increasing the speed of the spindle motor 103, in step 304 the disc crack detection algorithm shown in Figure 2 is performed. In other words, it is determined whether a disc has a crack while the speed of the disc drive is being increased.

[0038] In step 305 it is determined whether a disc crack detection signal is generated as the result of the disc crack detection algorithm performed in the step 304. If the disc crack detection signal is not generated, in step 306 it is determined whether the spindle motor 103 rotates at target revolutions per minute (rpm) corresponding to the target speed St. If the speed of the spindle motor 103 does not reach the target rpm, the process goes back to the step 303 and the steps described above are repeated.

[0039] If it is determined that the disc crack detection signal is generated in the step 305, the target speed is automatically changed to a low speed in step 307. In step 310, servo control factors and circuit factors are reset with respect to the changed speed. Here, the low speed may be the minimum speed of the disc drive, or the target speed can be sequentially lowered according to predetermined steps.

[0040] With such an arrangement, the disc crack detection algorithm is performed when the speed of a disc drive is increased, and the speed can be automatically lowered if it is determined that a disc has a crack. In the embodiment of Figure 3, the disc crack detection algorithm is performed only when the speed of a disc drive is increased. However, the disc crack detection algorithm can be performed in the same manner as described above when the speed is decreased so that the speed can be controlled to be lower than a target speed when a crack is detected.

[0041] A method of controlling the speed of a disc drive according to a second embodiment of the present invention will now be described first with reference to Figures 1 and 4. In step 401, the system controller 109 determines whether a current play mode is changed into a pause mode. If the play mode is changed into the pause mode, in step 402 the value Cd of a down counter within the system controller 109 is initialized to Xo, and down counting is performed to repeatedly perform the disc crack detection algorithm for a predetermined period of time.

[0042] In step 403 the disc crack detection algorithm shown in Figure 2 is preformed. In step 404, it is determined whether a disc crack detection signal is generated as the result of the disc crack detection algorithm. If the disc crack detection signal is generated, in step 407 a target speed is changed into a low speed. The speed is lowered to stabilize the disc drive when a disc has a crack.

[0043] If the disc crack detection signal is not generated, in step 405 it is determined whether the value Cd of the down counter is zero. If the value Cd is zero, this disc drive speed control process ends without changing the target speed. Otherwise, since the period of time for which the disc crack detection algorithm is repeatedly performed has not elapsed, the pause mode is maintained in step 406. If the pause mode is maintained, the process proceeds to the step 403 and is repeated.

[0044] With such an arrangement, the disc crack detection algorithm is repeated for a predetermined period of time starting from a point when the mode is changed into a pause mode, and a target speed is automatically changed into a low speed when a disc crack is detected.

[0045] A method of controlling the speed of a disc drive according to a third embodiment of the present invention will now be described with reference to Figures 1 and 5. In the disc drive speed control method according to the second embodiment shown in Figure 4, the disc crack detection algorithm is performed only for a predetermined period of time in an initial stage when a play mode is converted into a pause mode, and the speed of a disc drive is automatically changed into a low speed when a disc crack is detected. But, in the disc drive speed control method according to the third embodiment shown in Figure 5, the disc crack detection algorithm is performed periodically during a pause mode.

[0046] Referring to Figure 5, in step 501 the system controller 109 determines whether the play mode of a disc drive is changed into a pause mode. If the play mode is changed into the pause mode, in step 502 the disc crack detection algorithm of Figure 2 is performed periodically. In step 503 it is determined whether a disc crack detection signal is generated as the result of the disc crack detection algorithm performed in the step 502. If the disc crack detection signal is generated, in step 505 a target speed is changed to a low speed. If the disc crack detection signal is not generated as the result of the step 503, it is determined whether the pause mode is maintained in step 504. If the pause mode is maintained, the process proceeds to the step 502.

[0047] A method of controlling the speed of a disc drive according to a fourth embodiment of the present invention will now be described with reference to Figures 1 and 6. In step 601 the system controller 109 determines whether a condition of execution of the disc crack detection algorithm is satisfied. If the condition is satisfied, in step 602 the disc crack detection algorithm of Figure 2 is performed. In step 603 it is determined whether a disc crack detection signal is generated as the result of the disc crack detection algorithm. If the disc crack detection signal is not generated, the process goes back to the step 601. If the disc crack detection signal is generated, in step 604 a target speed is changed into a low speed. In step 605, warning message data informing that a disc crack is detected is transmitted to the host computer 112 through the interface unit 111 so that a user can recognize that a loaded disc has a crack.

[0048] The present invention can be realized as a method, an apparatus, a system and so on. When the present invention is realized as software, the members of the present invention are code segments which execute necessary operations. Programs or code segments may be stored in a processor readable medium or may be transmitted by a transmission medium or by a computer data signal combined with a carrier in a communication network. The processor readable medium may be any medium, such as an electronic circuit, a semiconductor memory device, a ROM, a flash memory, an erasable ROM, a floppy disc, an optical disc, a hard disc, an optical fiber medium, or a radio frequency (RF) network, which can store or transmit information. The computer data signal may be any signal which can be transmitted through a transmission medium such as an electronic network channel, an optical fiber, air, an electromagnetic field, or a RF network.

[0049] As described above, the present invention automatically determines whether a disc loaded on a disc drive has a crack in a specific mode, and automatically changes a target speed into a low speed when it is determined that the disc has a crack, thereby exactly checking the crack state of the disc during action of the disc drive, decreasing the percentage of error occurrence, and reducing the probability of damage to the disc.

[0050] Although the invention has been described with reference to particular embodiments, it will be apparent to one of ordinary skill in the art that modifications to the described embodiments may be made without departing from the scope of the invention. Therefore, it is obvious that the present invention is not restricted to the specific structures or arrangements shown or described in this specification.

[0051] The reader's attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

[0052] All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

[0053] Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

[0054] The invention is not restricted to the details of the foregoing embodiment(s). The invention extend to

any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

Claims

1. A method of detecting a crack in a disc loaded on a disc drive, the method comprising the steps of:

   (a) determining whether the disc drive satisfies an initially set condition for execution of a disc crack detection algorithm;

   (b) counting the number of a type of error signals whose levels exceed a predetermined threshold voltage, at predetermined measuring time periods, when it is determined that the disc drive satisfies the initially set condition in the step (a); and

   (c) generating a disc crack detection signal when the number of the type of error signals counted in the step (b) exceeds a predetermined number.

2. The method of claim 1, wherein the condition for execution of a disc crack detection algorithm is set such that the disc crack detection algorithm is performed whenever a play mode is changed into a pause mode.

3. The method of claim 1 or 2, wherein the condition for execution of a disc crack detection algorithm is set such that the disc crack detection algorithm is performed at predetermined time intervals in a pause mode.

4. The method of claim 1, 2 or 3, wherein the condition for execution of a disc crack detection algorithm is set such that the disc crack detection algorithm is performed whenever the target speed of the disc drive is changed.

5. The method of claim 4, wherein the condition for execution of a disc crack detection algorithm is set such that the disc crack detection algorithm is performed whenever the target speed increases.

6. The method of any preceding claim, further comprising the step of transmitting warning message data to a host computer when the disc crack detection signal is generated.

7. A method of controlling the speed of a disc drive, comprising the steps of:

   (a) determining whether a command instructing changing of the speed of the disc drive to a target speed is input;

   (b) controlling the speed of a spindle motor to be the target speed according to the command;

   (c) counting the number of a type of error signals whose levels exceed a predetermined threshold voltage, at predetermined measuring time periods until the current speed reaches the target speed;

   (d) generating a disc crack detection signal when the number of the type of error signals counted in the step (c) exceeds a predetermined number; and

   (e) changing the target speed into a predetermined low speed when the disc crack detection signal is generated.

8. A method of controlling the speed of a disc drive, comprising the steps of:

   (a) determining whether a current play mode is changed into a pause mode;

   (b) counting the number of a type of error signals whose levels exceed a predetermined threshold voltage, at predetermined measuring time periods, when it is determined that the play mode is changed into the pause mode in the step (a);

   (c) generating a disc crack detection signal when the number of the type of error signals counted in the step (b) exceeds a predetermined number; and

   (d) changing a target speed into a predetermined low speed when the disc crack detection signal is generated.

9. The method of any preceding claim, wherein the type of error signals comprise tracking error signals.

10. The method of any of claims 1 to 8, wherein the type of error signals comprise focus error signals.

FIG. 1

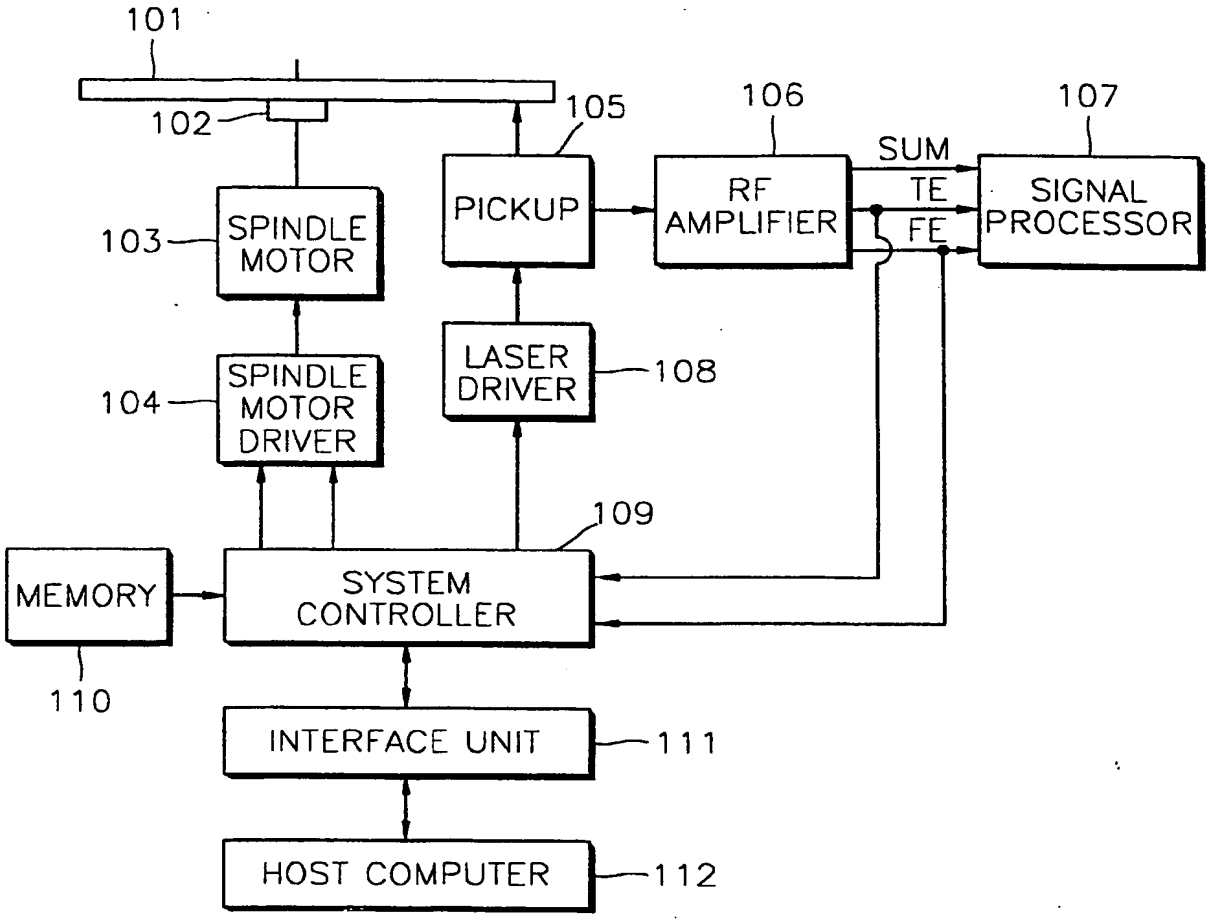

FIG. 2

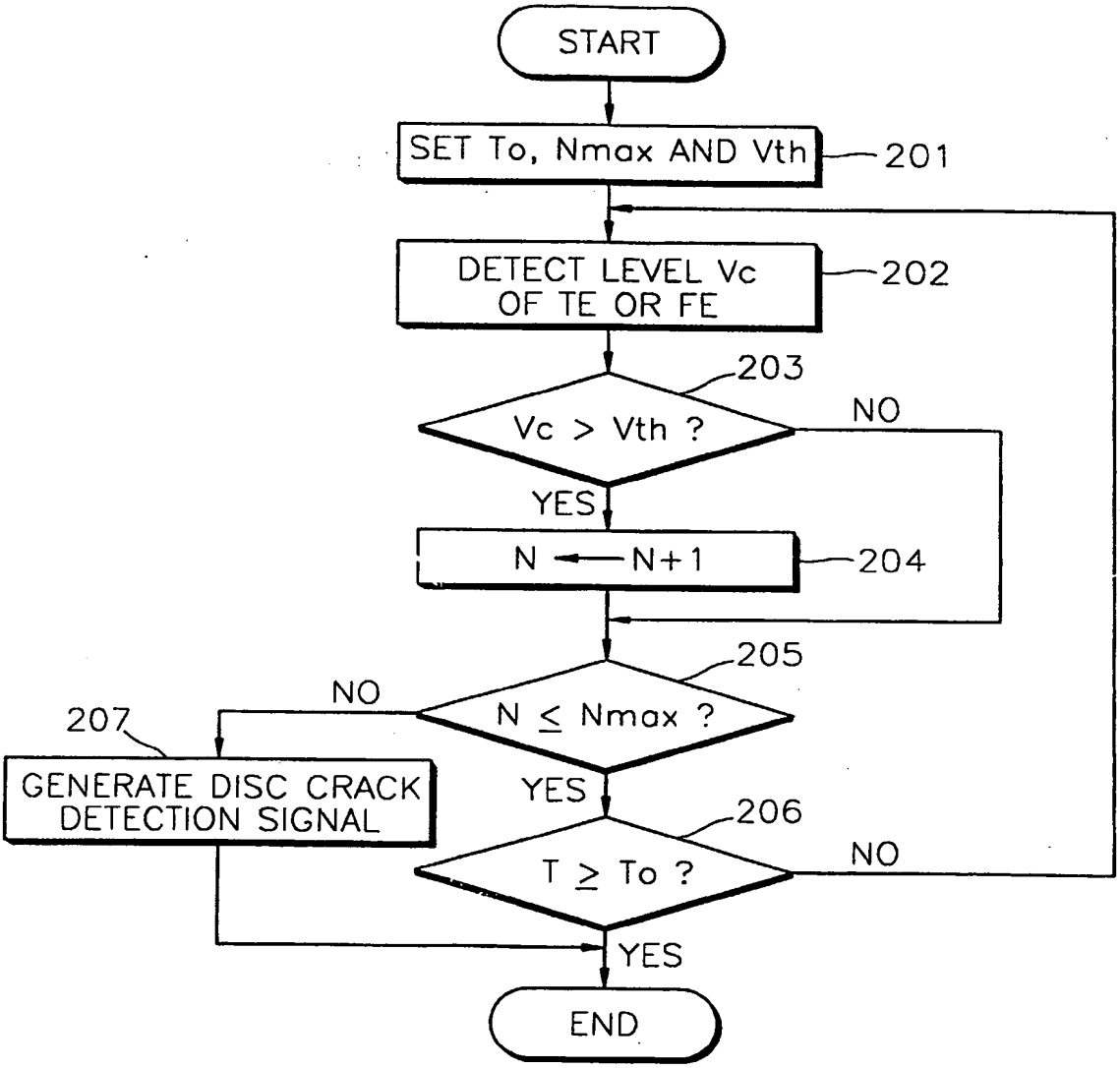

FIG. 3

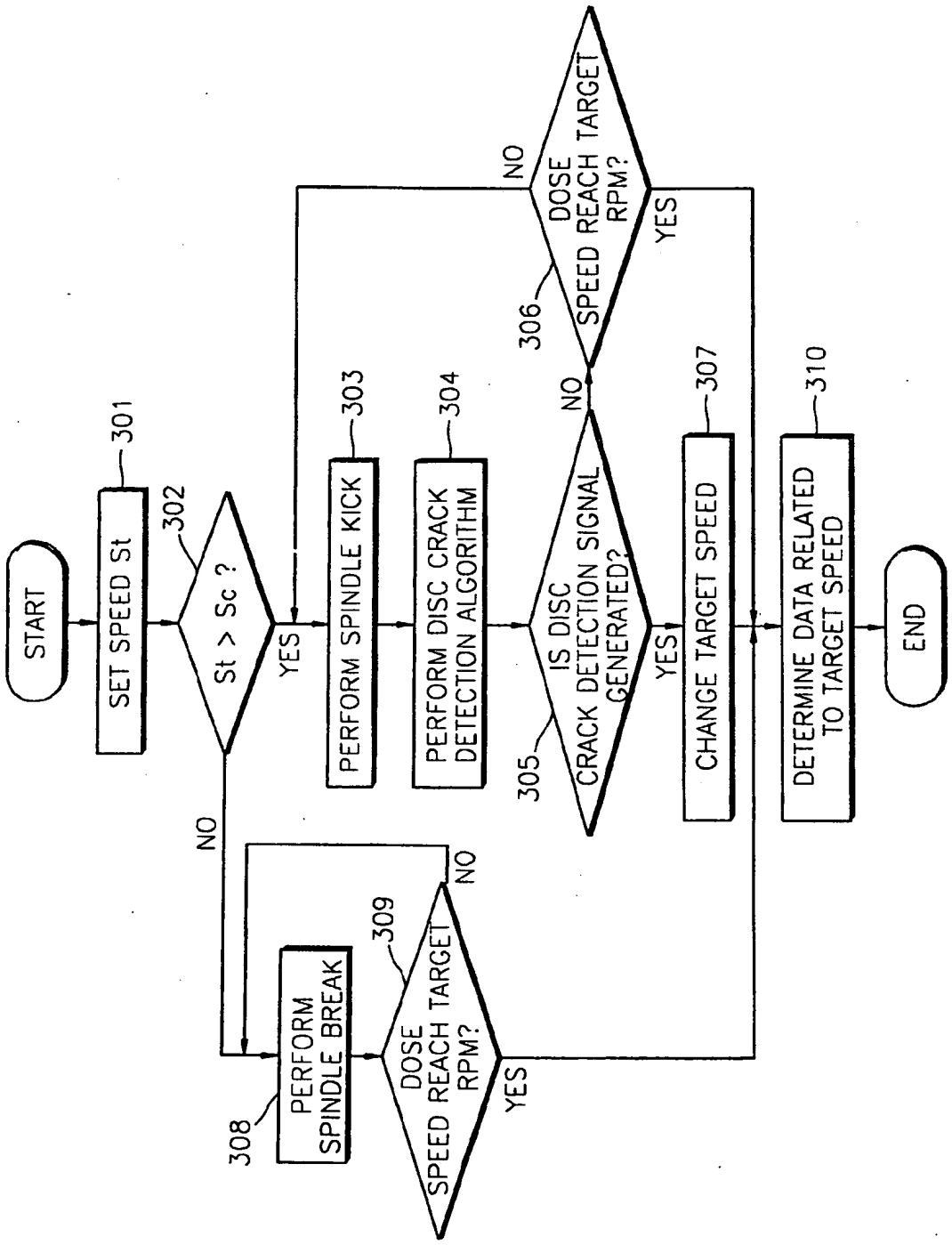

FIG. 4

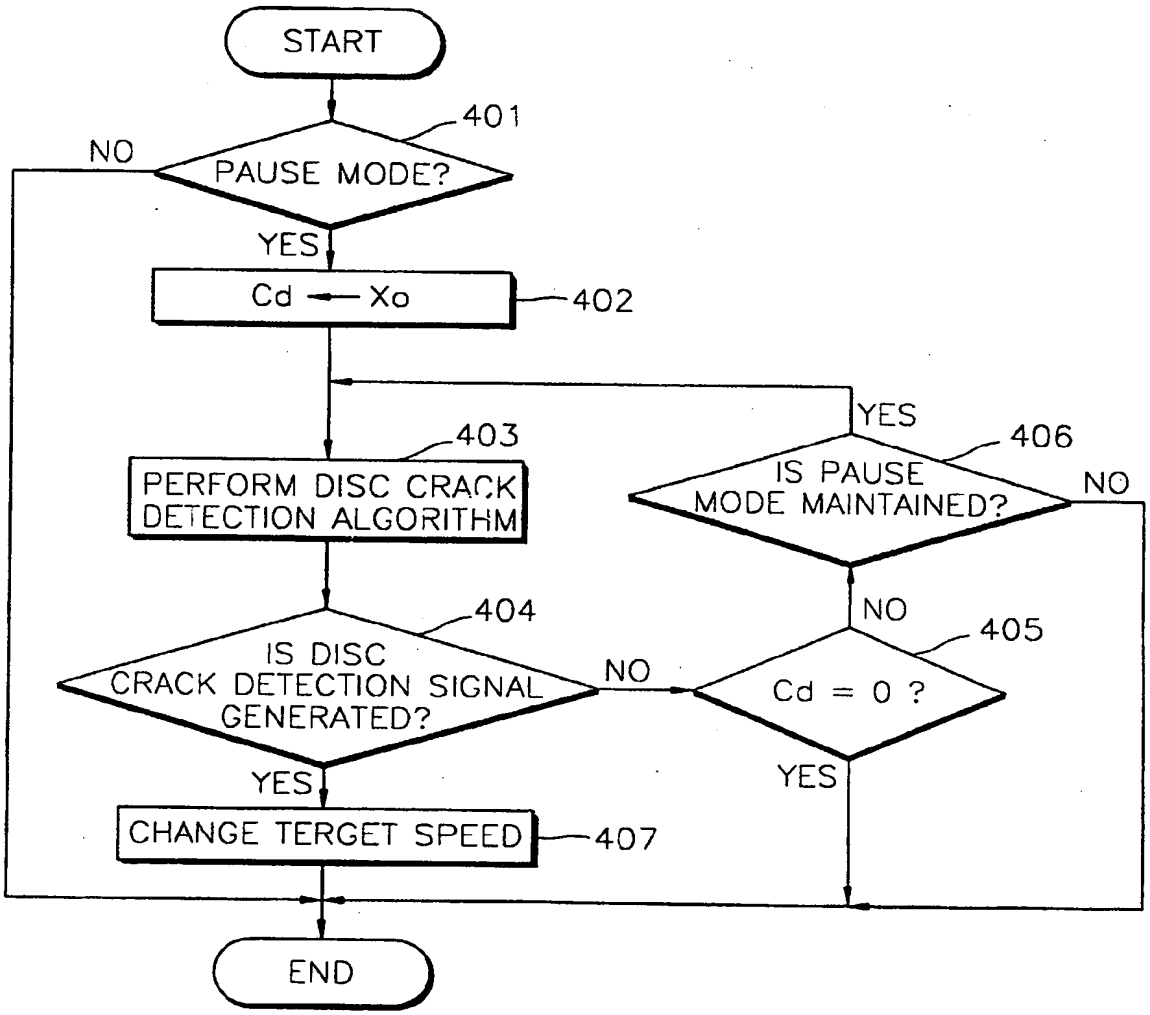

FIG. 5

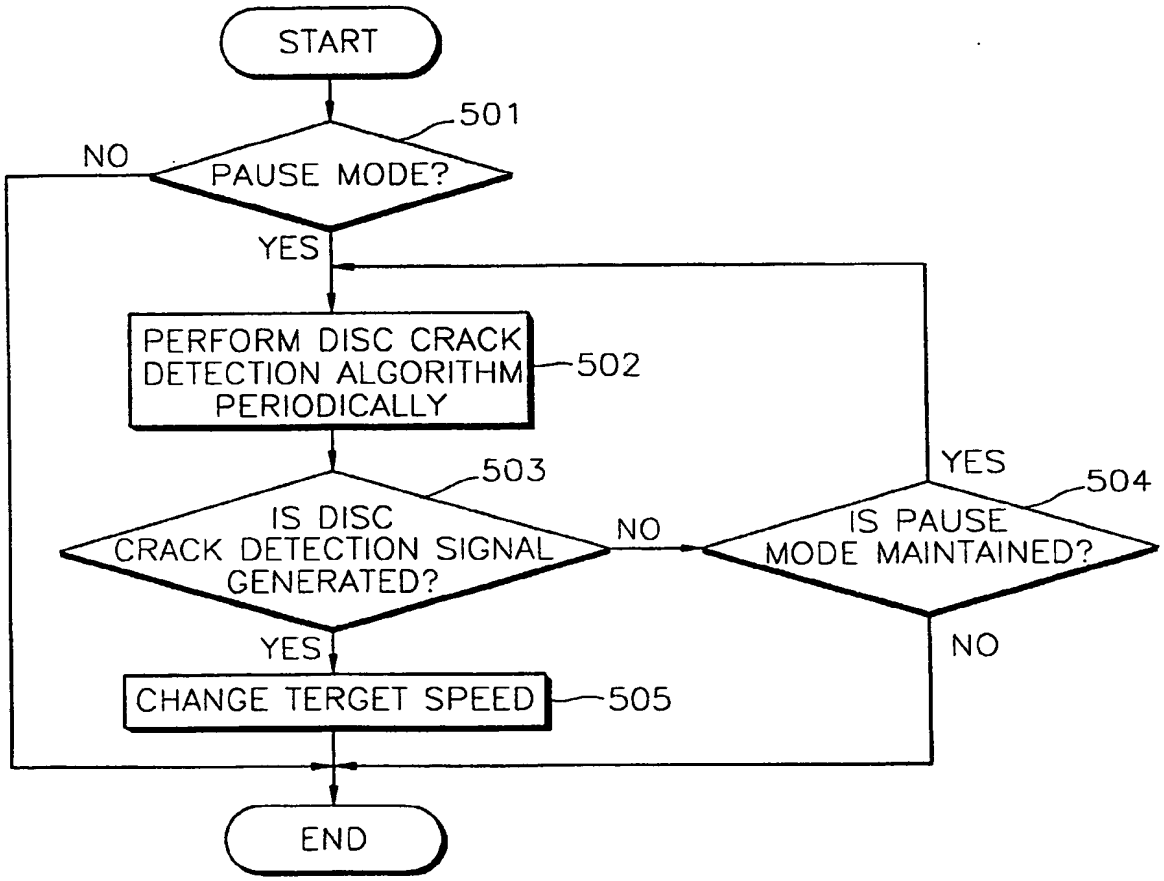

FIG. 6

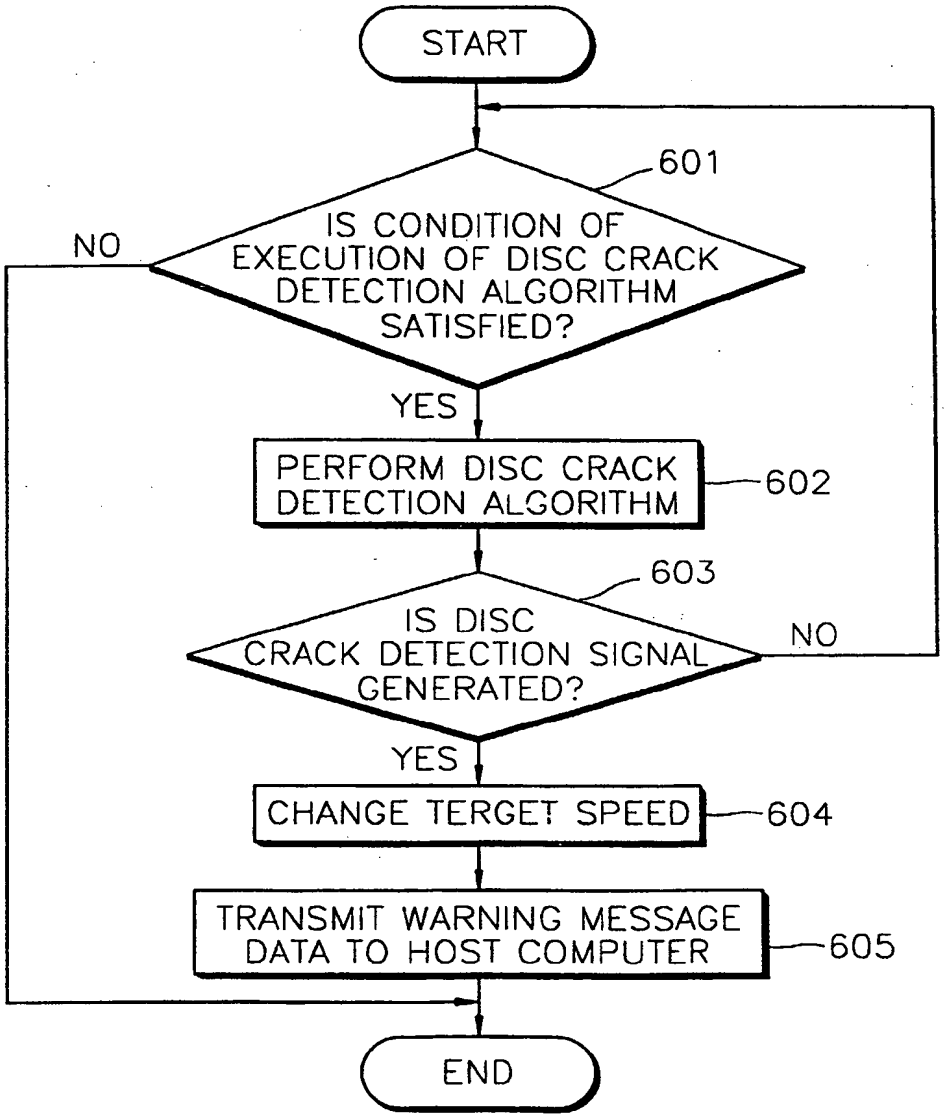

FIG. 7A

FIG. 7B

FIG. 8A

FIG. 8B

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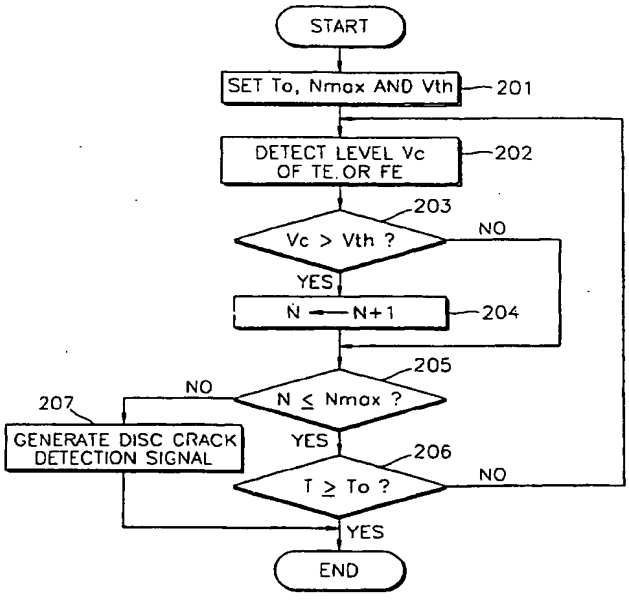
FIG. 2



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EUROPEAN SEARCH REPORT

Application Number
EP 01 30 7300

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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TECHNICAL FIELDS SEARCHED (Int.Cl.7)

G11B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	10 March 2003	Malagoli, M

CATEGORY OF CITED DOCUMENTS

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